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Technical Notes and Surgical Techniques

Revisiting the far lateral approach in the treatment of lesions located at the craniocervical junction—Experiences from West China hospital, Sichuan University, Chengdu☆

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ABSTRACT

Far lateral approach is a modification of the traditional lateral suboccipital approach that provides adequate exposure of the ventral craniocervical junction. Lesions located at ventral aspect of brainstem and foramen magnum areas like the lower clivus and premedullary area, intradural segment of the vertebral artery and its branches, including the posteroinferior cerebellar artery, the lower cranial and upper cervical nerves can be accessed through far lateral exposure. Between January 2011 and June 2014, 17 patients with lesions located at the ventral aspect of brainstem and foramen magnum areas were treated in our institution using a far lateral approach. We reviewed the nature of lesions, treatment strategy and outcomes in those 17 patients with the approval of institutional review board. There were 10 female and 7 male patients with age ranging from 6 to 58. Pathological entities comprised 11 meningiomas, 2 subarachnoid cyst, 2 epidermoid cysts, 1 vertebral aneurysm and 1 brainstem glioma. All patients recovered well after surgery without severe complications. In conclusion, far lateral approach provides an optimal exposure to the ventral aspect of brainstem and foramen magnum area which is sufficient for total removal of anteriorly placed well circumscribed lesions with zero retraction of neural axis.

1. Introduction

Far lateral approach is a modification of the traditional lateral suboccipital approach that provides adequate exposure of the ventral craniocervical junction [6,9,11]. Lesions located at ventral aspect of brainstem and foramen magnum areas like the lower clivus and premedullary area, intradural segment of the vertebral artery (VA) and its branches, including the posteroinferior cerebellar artery (PICA), the lower cranial and upper cervical nerves can be accessed through far lateral exposure [8,11]. This study focuses on the treatment of lesions located at the ventral aspect of brainstem and foramen magnum areas using a far lateral approach.

2. Materials and methods

Between January 2011 and June 2014, 17 patients with lesions located at the ventral aspect of brainstem and foramen magnum areas were treated in our institution using a far lateral approach. We reviewed the nature of lesions, treatment strategy and outcomes in those 17 patients with the approval of an institutional review board.

2.1. Surgical technique

2.1.1. Patient positioning

The patient was placed in a park bench position, with the head slightly tilted toward the floor and fixed by the head holder to open up the space between the edge of the mastoid and the transverse process of the atlas (Fig. 1A).

Intraoperative monitoring of the cranial nerves (V–XII) was performed in all cases using superficial electrodes and intratracheal electrodes.

2.1.2. Skin flap

Antibiotics were administered intravenously approximately 30 minutes prior to making the skin incision. Skin incision was made, starting from mid-external occipital protuberance, then turned laterally just above the superior nuchal line, reached the mastoid, and turned downward in front of the posterior border of the sternocleidomastoid muscle onto the lateral aspect of the neck about 3 cm below the tip of the mastoid process where transverse process of the atlas can be palpated through the skin (Fig. 1A).

☆ Conflict of Interest: None declared.

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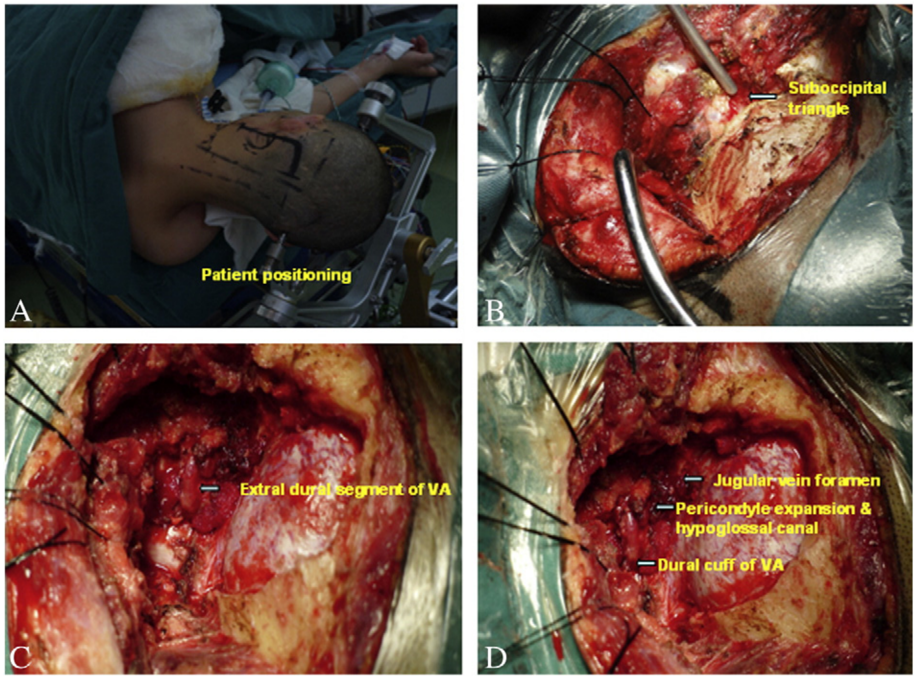

Fig. 1. Far lateral approach. (A) Park bench position with skin incision marking. (B) Exposure of suboccipital triangle after muscle dissection in layers. (C) Intraoperative view after suboccipital craniectomy and C1 hemilaminectomy. (D) Intraoperative view after drilling one third of occipital condyle.

2.2. Muscle dissection and exposure of the transverse process of atlas

Suboccipital muscles were carefully dissected in layers leaving a musculofascial cuff attached along the superior nuchal line for closure. The skin flap was reflected downward and medially while exposing the suboccipital triangle (Fig. 1B). During the dissection touching the transverse process of the atlas, a key landmark located between the mastoid process and the mandibular angle is very important in completing the exposure because several important muscles are attached to it, for example, the rectus capitis lateralis, the superior and inferior oblique muscles. The suboccipital triangle is limited by three muscles: above and medially by the rectus capitis posterior major, above and laterally by the superior oblique, and below and laterally by the inferior oblique. The jugular vein, facial and vagus nerve covered by the rectus capitis lateralis should be protected carefully.

2.3. Craniectomy procedure and drilling landmarks

At first the suboccipital craniectomy should be completed before the exposure of the vertebral artery. The extradural stage begins with a suboccipital craniectomy, identification of the occipital condyle, and removal of at least half of the posterior arch of the atlas. Two osseous landmarks, asterion and the inion, are important in planning the suboccipital craniectomy. The asterion provides external landmark for the transverse-sigmoid junction, and a line drawn from the root of the zygoma to the inion (the superior nuchal line) is a good approximation of the transverse sinus. The sigmoid sinus runs along the digastric groove posterior to the mastoid eminence. A lower suboccipital craniectomy was performed. A burr hole was placed about 3 cm below the asterion. While making the burr hole, the bone should be drilled with a cutting burr leaving a thin shell of cortical bone, which could be safely removed with a Penfield dissector or curet. Before the craniectomy procedure, the epidural space should be confirmed by peeling the dura attached with bone using the Penfield dissector. Thereafter, craniectomy was done carefully below the transverse sinus and behind the sigmoid sinus. The bone up to the medial edge of the sigmoid sinus was rongeured after the removal of bone flap. The lateral rim of the foramen magnum was resected. The lateral margin of the craniectomy was expanded laterally using diamond drill and rongeur to expose the sigmoid sinus and jugular foramen. If the sinus got lacerated during drilling, Gelfoam should be laid on top of the hole, followed by a cottonoid compression. The sigmoid sinus is especially susceptible to injury because of its thin outer wall and curved bony groove. In older patients, the lateral wall of the sinus is usually adherent to the bone and may be damaged if not carefully separated from the bone before the craniectomy. Opening of the mastoid air cells at the lateral margin of the bony opening should be obliterated with bone wax to avoid leakage of CSF. Drilling of the posterior wall of occipital condyle using a diamond burr was done carefully protecting hypoglossal canal which is located above the middle third of the occipital condyle intracranially when necessary. The posterior arch was drilled laterally very carefully and reached the lateral side of transverse process (Fig. 1C–D).

2.4. Exposure of the VA

The vertebral artery courses from the transverse foramen of the C1 lateral mass through the sulcus arteriosus of the C1 vertebral arch. After the removal of posterior arch of C1 with a diamond burr to the lateral aspect of dura, a fat pad could be seen covering the vertebral artery. The fat pad on the surface of the vertebral artery hides venous plexus surrounding the artery which could be the source of profuse bleeding. During exposure of the vertebral artery, careful blunt dissection along this fat layer is important to protect the vertebral artery from damage. Bleeding from those venous plexus could be controlled with the hemostat material or low voltage bipolar cautery. After dealing with the prevertebral venous plexus, complete exposure of suboccipital segment of the vertebral artery could be done with blunt dissection. Exposing and mobilizing suboccipital segment of the vertebral artery allowed full proximal control of the artery, and transposing this segment allowed safe drilling of the condyle.

2.5. Exposure of lesion and excision

The dural incision began behind the sigmoid sinus and extended behind the vertebral artery into the upper cervical area (Fig. 2C). The upper

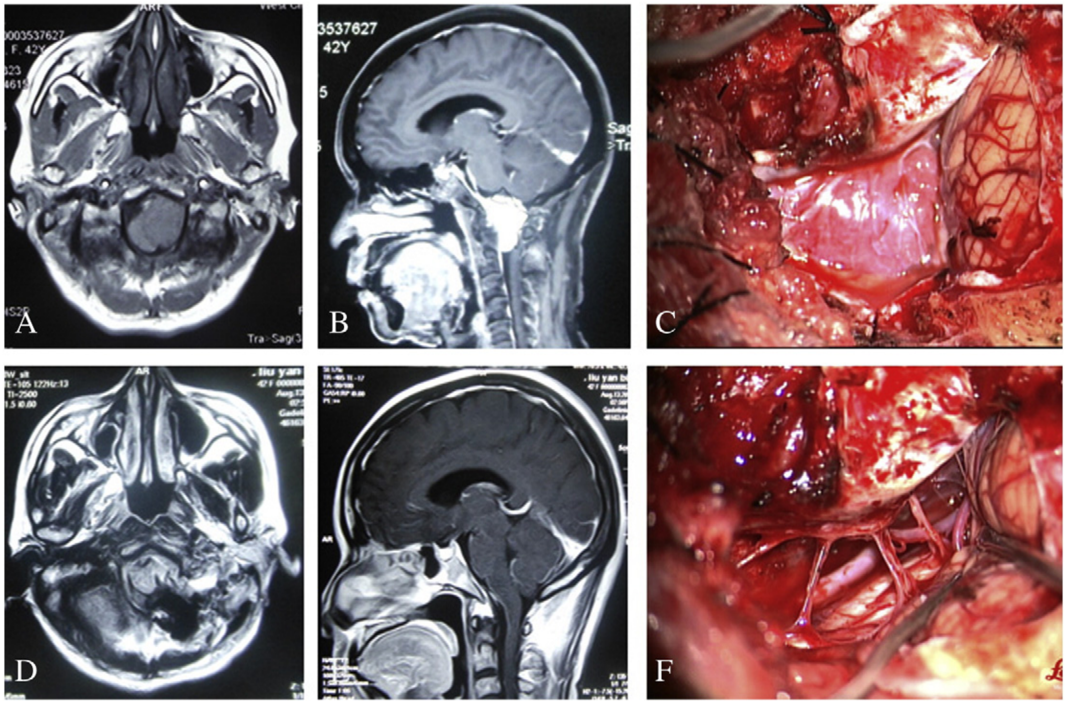

Fig. 2. (A) Axial MRI showing isointense tumor in right foramen magnum compressing the neural axis. (B) GD-DTPA contrast enhanced MRI showing highly enhanced tumor. (C) Intraoperative photo showing the tumor. (D) Post-operative axial MRI showing the complete removal of tumor. (E) Post-operative sagittal MRI showing the complete removal of tumor. (F) Intraoperative photo after complete removal of tumor.

extent of the dural opening depends on how much of the cerebellopontine angle is to be exposed. Care should be taken during the dural opening and mobilization of the vertebral artery. The dural cuff around the vertebral artery could be left unresected. Retractor-less surgical exposure and low electric coagulation was the key point after the dural opening to avoid irretrievable heat injury to the brainstem and surrounding structures. Cavitron Ultrasonic Aspirator (CUSA) was preferred than the usage of bipolar cautery while resecting the lesion.

2.6. Closure

Closure was done with water tight stitching of the dura after complete or partial resection of the lesion. We confirmed the complete obliteration of all mastoid air cells exposed. Fibrin glue was used to seal the linings of dural closure as well as obliterate all mastoid air cells exposed. Skull base was re-constructed by replacing bone flap using titanium plates and screws. Muscles and skin were closed in layers.

2.7. Postoperative care

Extubation should be done only after the patient completely awakes to avoid aspiration caused by possible lower cranial nerve dysfunction. A nasogastric tube was placed in patients who showed signs of swallowing dysfunction. A tracheotomy was indicated if a patient experienced difficulty in swallowing and recurrent aspiration.

Table 1
Ventral aspect lesions of the brainstem and foramen magnum areas.

Case no.	Age (years)	Gender	Extent of resection	Neuro-deficits before surgery	Diagnosis	Neuro-deficits and recurrence at one month after surgery
1	12	M	T	N	Meningioma WHO1	N/NR
2	57	F	T	Dysphagia	Clear cell meningioma (CCM) WHO2	N/NR
3	42	F	T	N	Meningioma WHO1	N/NR
4	36	M	T	N	Meningioma WHO1	N/NR
5	47	F	T	N	Meningioma WHO1	N/NR
6	58	F	T	Dysphagia	Meningioma WHO1	N/NR
7	55	F	T	N	Meningioma WHO1	N/NR
8	62	M	T	N	Meningioma WHO1	N/NR
9	53	F	T	N	Meningioma WHO1	N/NR
10	57	F	T	Dysphagia	Meningioma WHO1	N/NR
11	46	F	T	N	Meningioma WHO1	N/NR
12	22	M	T	N	Subarachnoid cyst	N/NR
13	36	M	T	N	Subarachnoid Cyst	N/NR
14	58	F	Clip and resection	Weakness of right limb	Right vertebral V5 segment giant aneurysm	Weakness of right limb/NR
15	6	M	T	N	Epidermoid cyst	N/NR
16	13	M	T	N	Epidermoid cyst	N/NR
17	24	F	P	Paresis of right side, dysphagia	Glioblastoma multiforme (WHO IV)	Dysphagia

M, male; F, female; T, total resection; P, partial resection; N, none; NR, no recurrence.

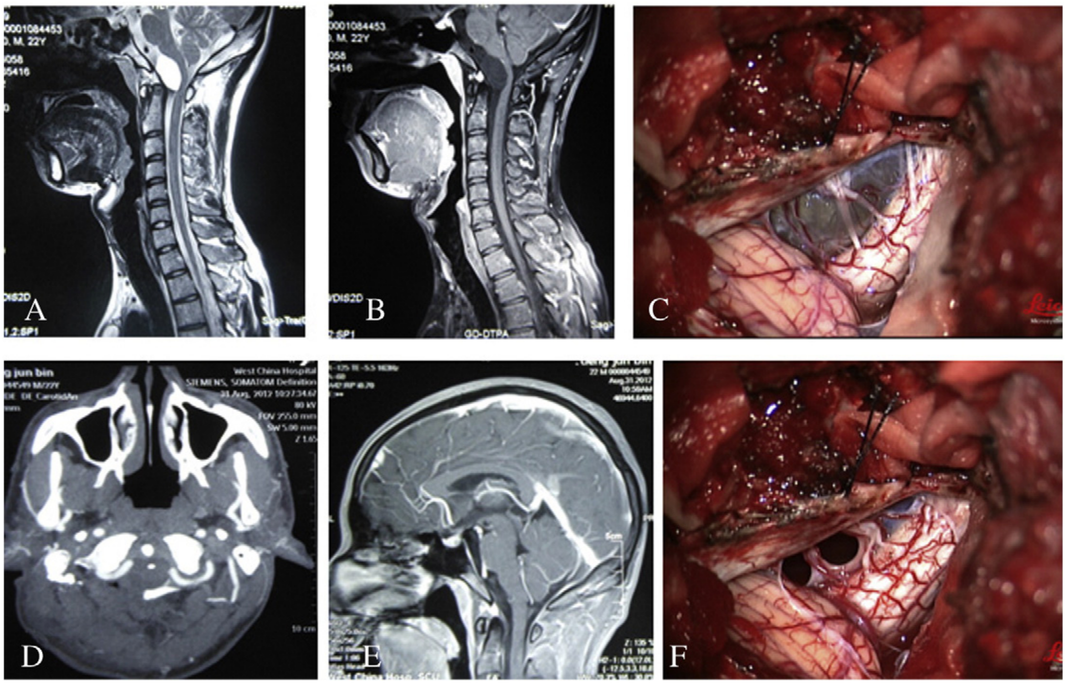

Fig. 3. (A) T2 MRI showing a homogenously intense high signal lesion at craniocervical junction compressing the neural axis. (B) GD-DTPA contrast enhanced MRI showing unenhanced lesion. (C) Lesion exposed intraoperative photo showing the sub-arachnoid cyst. (D) Post-operative axial MRI showing complete removal of the lesion. (E) Post-operative sagittal MRI showing complete removal of the lesion. (F) Intraoperative photo showing complete removal of the cyst.

3. Results

There were 10 female and 7 male patients with age ranging from 6 to 58. Pathological entities comprised 11 meningiomas, 2 subarachnoid cysts, 2 epidermoid cysts, 1 vertebral aneurysm and 1 brainstem glioma (Table 1). All patients recovered well after surgery without severe complications.

3.1. Case illustrations

3.1.1. Case I: Typical meningioma

A 42-year-old woman with a history of numbness of upper limbs for 20 days was admitted in our hospital. Physical examination revealed hyposthesia of both upper limbs and left thenar eminence atrophy. Magnetic resonance imaging showed a heterogenous isointense lesion in the ventral aspect of the brainstem and foramen magnum significantly compressing the medulla and cervical spinal cord (Fig. 2A–B). By the far lateral approach the tumor was exposed. The dural incision was done starting behind the sigmoid sinus and extended behind the vertebral artery into the upper cervical area. The dural cuff around the vertebral artery was left unresected. Adequate exposure of the lesion was obtained with blunt dissection. The tumor was vascular, moderate in consistency, covered by the arachnoid mater and displacing the cranial nerves (Fig. 2C). CUSA was used for the tumor resection. After total resection of the tumor (Fig. 2F), water tight dural suturing was done. The cranium was re-constructed using titanium mesh. The patient was stable postoperatively and discharged on 7th postoperative day with Glasgow Outcome Score (GOS) of 5 (Table 1: case no. 3).

3.1.2. Case II: Subarachnoid cyst

A 22-year-old man with a history of headache, dizziness and occasional difficulty in swallowing since 1 year was admitted in our hospital. Magnetic resonance imaging showed an oval homogenous lesion at the foramen magnum compressing the neural axis which was hyointense in T1, hyperintense in T2, and unenhanced even after injection of GD-DTPA contrast agent (Fig. 3A–B). The lesion was surgically exposed via the far lateral approach. The lesion was cystic containing transparent liquid, covered by the arachnoid and displacing the cranial nerves (Fig. 3C). With the blunt dissection the cystic membrane was resected and the fluid aspirated (Fig. 3F). Postoperative period was uneventful and was discharged with GOS 5. Postoperative MRI showed complete removal of subarachnoid cyst (Fig. 3D–E; Table 1: case no. 12).

3.1.3. Case III: Vertebral aneurysm

A 58-year-old woman with a history of weakness of right limb was admitted in our hospital. Computed tomography showed a ventrally located space occupying lesion at the posterior fossa (Fig. 4A). Computed tomographic angiography showed a right vertebral V5 segment aneurysm compressing the ventral medulla (Fig. 4B). Digital substraction angiography revealed right vertebral artery with a dome oriented superiorly (Fig. 4C). The aneurysm was surgically exposed via the far lateral approach. The aneurysm was saccular whose broad dome seemed thrombosed and was compressing the brainstem. With careful dissection, through the window between 9th–10th and 11th cranial nerves, the aneurysm was clipped under the microscope. The dome was incised to make sure of complete clipping. The vascular patency of the distal vertebral artery was confirmed by intraoperative vascular Doppler ultrasound. Closure was done with water tight dural suturing and titanium mesh cranioplasty (Fig. 4D). Postoperatively the patient was stable and discharged with GOS of 4 (Table 1: case no. 14).

3.1.4. Case IV: Glioblastoma multiforme (WHO IV) of the brainstem

A 24-year-old woman with a history of headache, dizziness, chocking and right sided paresis for 2 weeks was admitted in our hospital. Magnetic resonance imaging showed a hyperintense lesion in the ventral aspect of pons and medulla extending to foramen magnum (Fig. 5A). Using the far lateral approach, the lesion was exposed. The tumor was soft, vascular, grayish white with diffused margin and located at the ventral aspect of pons and medulla (Fig. 5B). Partial resection of the tumor was done (Fig. 5C). Postoperatively paresis improved but the dysphagia remained and discharged with nasogastric tube in situ. During discharge patient GOS was 5 (Table 1: case no. 17).

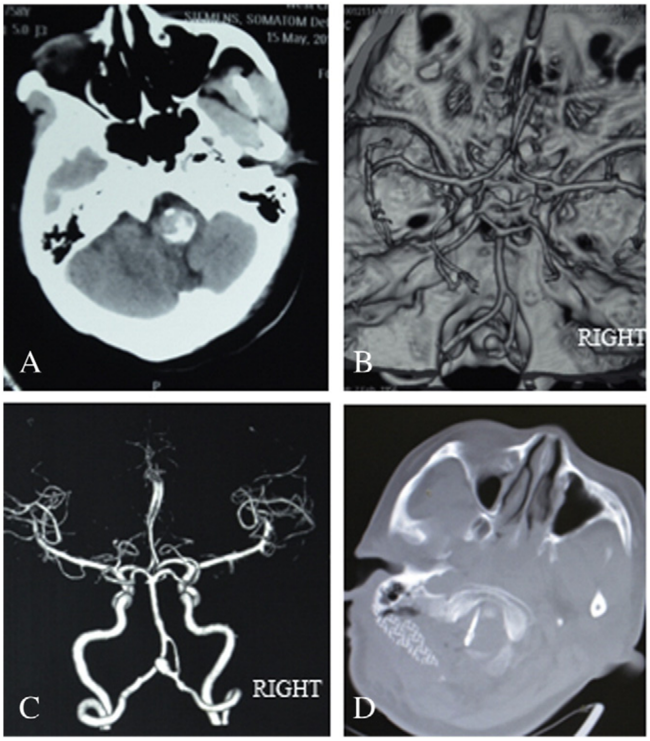

Fig. 4. (A) CT scan showing a hyperdense lesion showing at the ventral aspect of brainstem. (B) CTA showing right vertebral artery saccular aneurysm with superiorly directed dome. (C) DSA showing right vertebral artery saccular aneurysm. (D) Post-op CT showing clipped aneurysm.

4. Discussion

Management of lesions situated at the ventral aspect of brainstem and foramen magnum areas is challenging because of high morbidity and mortality [3,5,10]. Far lateral approach is often considered for such lesions. The far lateral approach is an extension of the standard suboccipital approach, is designed to maximize exposure of the lateroventral craniocervical junction and can be applied effectively to manage with a heterogeneous spectrum of pathological lesions involving this area [6,12]. The classic far lateral approach uses inverted "U" shaped or inverted hockey-stick suboccipital skin flap which provides good exposure of the muscular layers and has advantage of lesser retraction of the soft tissues of the head and neck [2,4,8]. Samii et al. [9] used C-shaped skin incision toward the ear with straight inferior extension toward the C2 spinous process thereby improving the lateral angle of the surgical corridor. We used inverted "L" shaped suboccipital skin flap which provided adequate exposure of VA and transverse process of C1. Our way had relatively less skin and muscle incision and especially focused on the ventral aspect of craniocervical junction.

The anterior transoral, far lateral or the extreme far lateral transcondylar approaches may be used for anteriorly or anteriolaterally placed lesions of the brainstem and foramen magnum [3,10]. Posterior and posteriolateral approaches, despite their simplicity, offer poor exposure and require retraction or rotation of the neural axis which might be hazardous [6,10]. Using retrosigmoid approach, it is very hard to expose the lesion adequately as well as needs unnecessary traction. The condylar fossa approach has a restricted angle of attack [12]. The transoral approach is a direct route to the lesion without having work around the brainstem, spinal cord and cranial nerves; however, lateral access of intradural lesions is limited by vertebral arteries and jugular vein [3,5,10]. In the far lateral approach, the jugular tubercle and occipital condyle are two major obstructions that may obstruct the view to the lower petroclival region, anterolateral surface of the brainstem, VA, and vertebrobasilar junction. The 1/3 resection of the condyle provides better visualization and a wider avenue of approach for the resection and treatment of lesions in this region [4,9,12]. It allows the surgeon to work with a view anterior to the neuraxis; hence, the brainstem, nerves and blood vessels could be protected by careful microscopic dissection.

We found meningioma to be the most common lesion located at ventral aspect of brainstem and foramen magnum areas. Subarachnoid cyst and epidermoid cyst are less common but may occur in this area. Lesions occurred here were often less symptomatic and found by accident. The most common symptom was dysphasia. Working space can be obtained between the 7th–8th cranial nerve complex and 9th–10th cranial nerves, between 9th–10th cranial nerves and 11th cranial nerves, or below the lower cranial nerves depending upon the extent of lesion and displacement of nerves. The space between 9th-10th cranial nerves and 11th nerves is usually wider than the space between 7th–8th and 9th–10th cranial nerves. Clipping of the aneurysms of the vertebrobasilar region utilizes the spaces between 7th–8th and 9th–10th cranial nerves for dissection, but the space below the lower cranial nerves is better for clip application [3,10]. Less heat injury is the key point during the whole surgery. CUSA is preferred than the usage of bipolar cautery to avoid irretrievable heat injury.

For the intracranial vertebral artery aneurysm, this is a good approach to supply an adequate exposure [2,12]. Most of the intracranial VA aneurysms are giant and often accompanied with intra-aneurysmal thrombosis compressing the brainstem. Study shows removal of one third of the occipital condyle produced a mean increase of 15.9-degree visibility [7] and provides greater angle of attack to the VA-PICA junction. The good intraoperative exposure through this approach makes the clipping of the aneurysm and removal of the intra-aneurysmal thrombosis easier. In one case reported in a series of PICA aneurysm cases, the aneurysm was located inferior and anterior to the hypoglossal canal and could not be exposed adequately through the condylar fossa approach. Conversion to the far lateral transcondylar approach allowed uncomplicated clipping of the aneurysm [12].

Brainstem glioma may grow toward the ventral aspect of pons and medulla oblongata. This approach is good for the biopsy and decompression of such lesions.

This approach is optimal depending on its retractor-less surgical exposure. It provides excellent exposure of the ventral spinomedullary junction with increased angle of attack, early and safe exposure of vascular

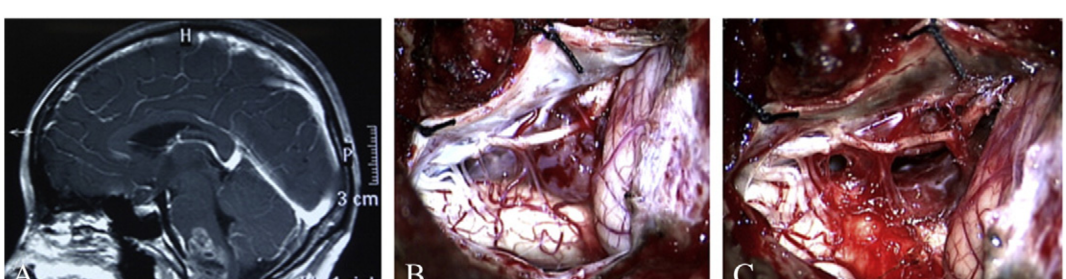

Fig. 5. (A) Sagittal MRI showing a diffuse heterogenous lesion in the ventral brainstem. (B) Intraoperative view of the lesion. (C) Intraoperative view after partial resection of the lesion.

structures, preservation of stability, elimination of the need for neuraxis retraction and simplicity of instruments and technique [4,5]. Compared with transoral approach, it provides the minimal risk of infection as this approach does not cross contaminated regions and enables a watertight dural closure to be performed. During the surgery we sometimes remove the posteromedial third of the condyle for the better exposure of the lesion, while argument remains that partial resection of the condyle is unnecessary, increases the duration of the operation, and can lead to instability at the craniocervical junction [1,7]. Biomechanical studies, however, have shown that resection of the posteromedial third of the occipital condyle is well tolerated and associated with no evidence of instability [12].

5. Conclusion

Far lateral approach requires a detailed anatomy of the craniocervical junction. This approach provides an optimal exposure to the ventral aspect of brainstem and foramen magnum area which is sufficient for total removal of anteriorly placed well circumscribed lesions with zero retraction of neural axis. Minimal heat injury and retractor-less surgical exposure help in protecting the brainstem, cranial nerves and blood vessels.

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